P24 Experimental and Computational Studies of Film Cooling With Compound Angle Injection

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Abstract

The University of Minnesota program is a combined experimental and computational study of various film-cooling configurations. Whereas a large number of parameters influence film cooling processes, this research focuses on compound angle injection. An appreciation of the advantages of compound angle injection has arisen recently but realizing the advantages will require improved understanding of the flow. This project should further this understanding.

Approaches being applied include: (1) a new measurement system that extends the mass/heat transfer analogy to obtain both local film cooling and local mass (heat) transfer results in a single system, (2) direct measurement of three-dimensional turbulent transport terms in a highly-disturbed flow, (3) measurement of film cooling effectiveness with in-flow temperature field measurements, (4) use of compound angle and shaped holes to optimize film cooling performance, and, (5) an exploration of anisotropy corrections to turbulence modeling of film cooling jets.

The outcome of this research is threefold. First, it provides fundamental scientific information in the form of detailed measurements, computational results, and turbulence model validation. Second, the results of the experiments and computations will be presented in a generalized form so that they will be directly usable by design engineers in industry. Providing input to numerical computation tools is one means by which these data are generalized. Finally, the experimental and computational activities will be used to familiarize graduate and undergraduate students with the gas turbine industry.

To date, research on turbulence generation and simulation of engine turbulence had been completed, test facilities for the experiment had been designed, constructed, and qualified, and modeling of film cooling proceeds. More recently, each of the facilities has been used to gather a significant amount of data to document in-line injection (the base case for the lateral injection study) and the turbulence models have been exercised to compute the film cooling flow fields and surface distributions. Also, lateral injection cases have begun with surveys of flowfields and qualification of the techniques.

The film-cooled test sections simulate the cooling arrangements of modern turbine cooling schemes. In one, surface mass transfer measurements have been taken using a modified method of measurement. This allows taking film cooling effectiveness and mass (heat) transfer coefficient data with very high spatial resolution. Another test section has been used to document turbulence transport in the coolant/mainstream mixing zone. Data showing the effects of film cooling flow on mean velocity and turbulence intensity in the mixing zone are given. Also, the eddy diffusivity of momentum for lateral transport is compared to the eddy diffusivity for transport normal to the test wall. The results lead to recommendations to the numerical modelers regarding how the anisotropy of the turbulence in the mixing zone should be modeled. The facility is now in the lateral injection configuration. The computational activity has begun with a study of the relative merits of parabolic and elliptic calculation procedures for film cooling flows. Also, the flow delivery plenum has been modeled. Finally, an analysis of the magnitude of thermal gradients in the airfoil wall imposed by film cooling has been presented.

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